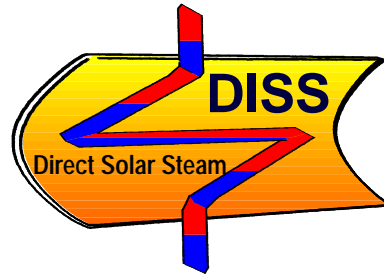


## The DISS project: Direct Steam Generation in parabolic troughs *Operation and Maintenance experience. Update on project status*



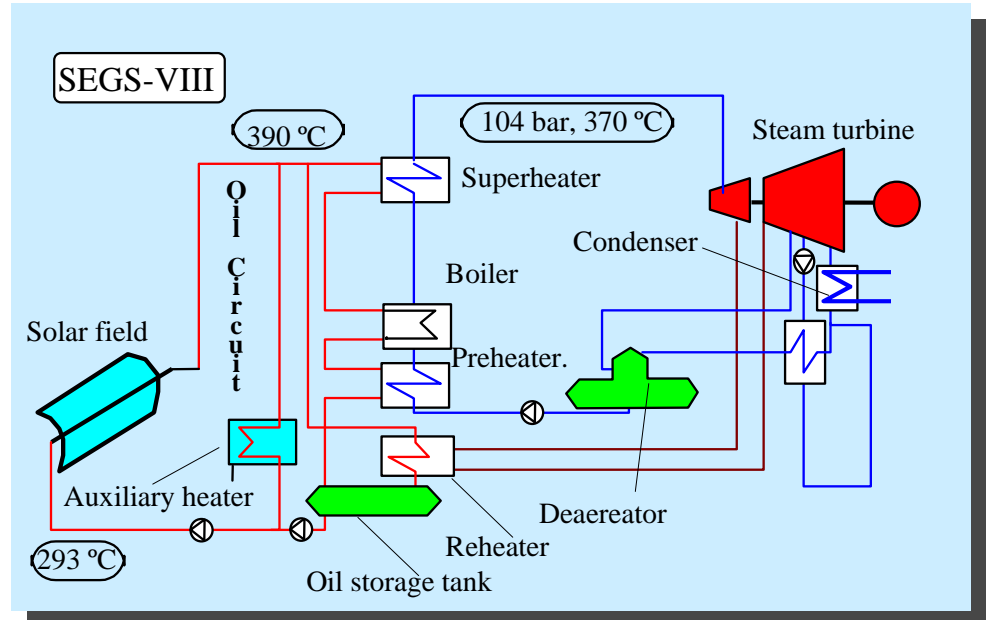
**Eduardo Zarza, Loreto Valenzuela, Javier León**

CIEMAT-Plataforma Solar de Almería, Apartado 22, Tabernas, E-04200 Almería, Spain

**Klaus Hennecke, Markus Eck, Martin Eickhoff, H.-Dieter Weyers**

Solare Energietechnik, Deutsches Zentrum für Luft- und Raumfahrt e.V., (DLR), Germany

**State-of-the-Art of Solar Thermal Power Plants with Parabolic troughs**



- 8 SEGS Plants currently in operation, with a peak power of 340 MWe
- Oil circuit (HTF) acting as heat carrier between the solar field and the BOP
- Rankine cycle with superheated steam at 370 °C / 104 bar
- Electricity production with natural gas is limited to 25% of annual output

## ➤ PROJECT OBJECTIVES:

DISS is a complete R+D program aimed at developing a new generation of Solar Thermal Power Plants with improved parabolic trough collectors and Direct Steam Generation (DSG) in the solar field, thus reducing costs while increasing the efficiency. There are two main items in DISS:

1. *Development of improved components for parabolic trough collectors*
2. *Development of the Direct Steam Generation (DSG) technology*

## ➤ PROJECT PHASES AND PARTNERS:

- **DISS-phase I** (with E.U. financial support under JOULE contract JOR3-CT95-058)

**Duration:** from January 1996 to November 1998

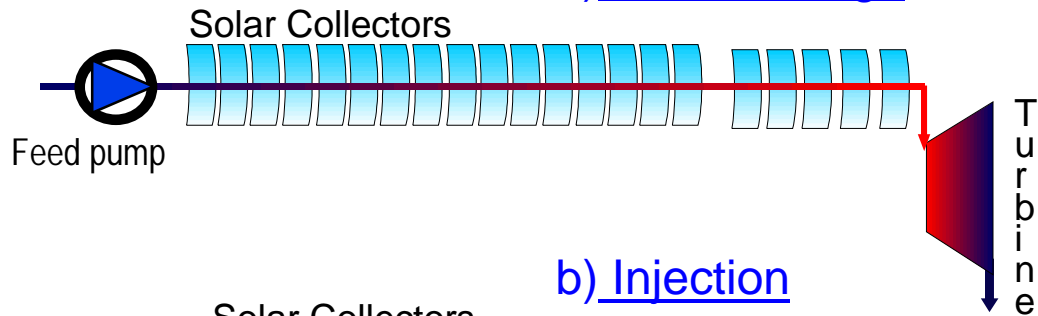
**Partners:** CIEMAT, DLR, ENDESA, IBERDROLA, INABENSA, PILKINGTON, SIEMENS, U.E.F., ZSW

- **DISS-phase II** (with E.U. financial support under JOULE contract JOR3-CT98-277)

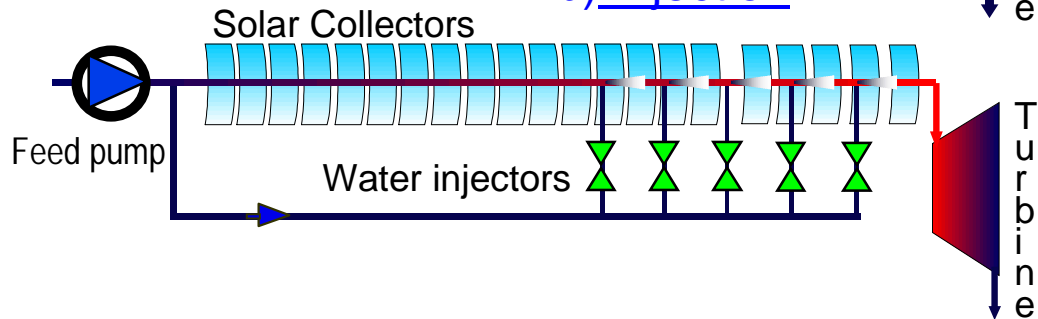
**Duration:** from December 1998 to August 2001

**Partners:** CIEMAT, DLR, ENDESA, IBERDROLA, INABENSA, INITEC, FLABEG, ZSW

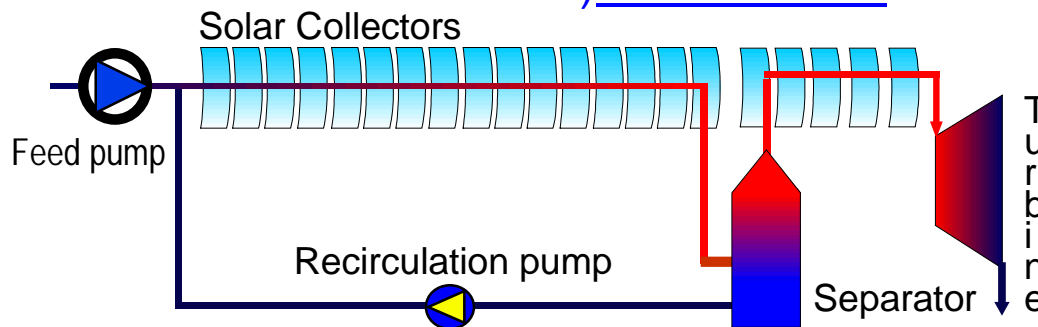
## a) Once-through



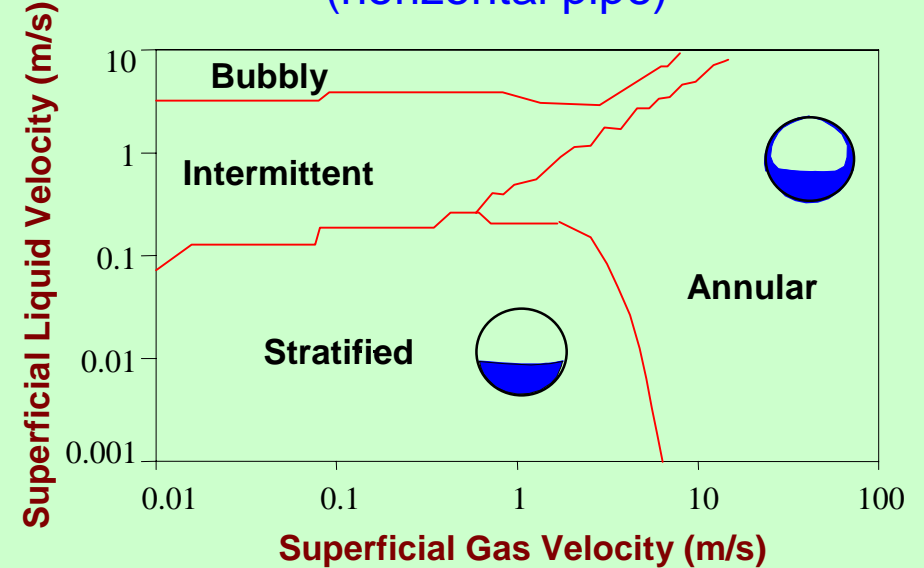
## b) Injection



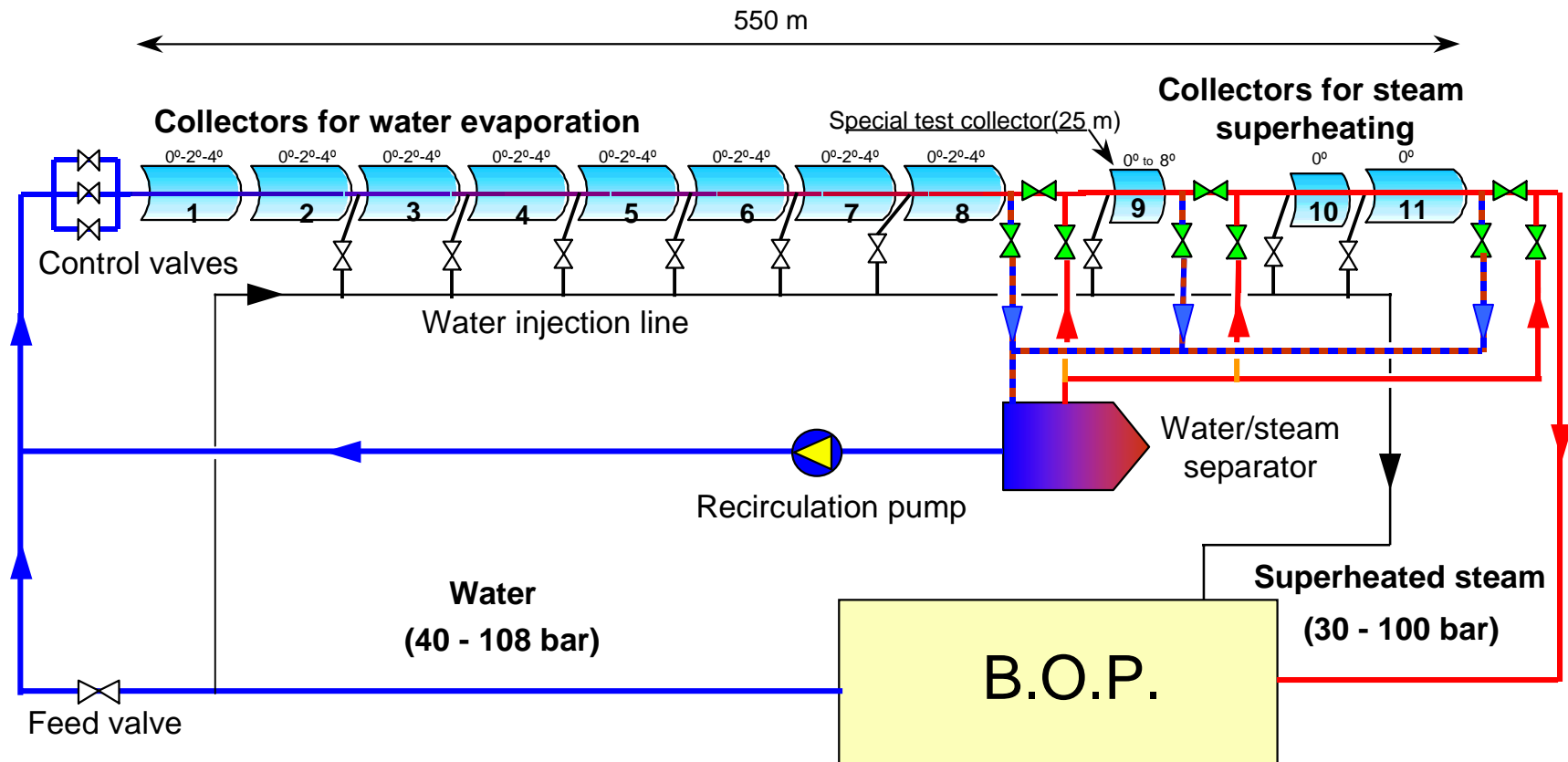
## c) Recirculation



## Two-phase Flow Pattern Map (horizontal pipe)



## Actual Configuration of the PSA DISS Test Facility



## Technical Characteristics of the PSA DISS Test Facility

No. of parabolic-trough modules	40
Module aperture/length:	5.76 m /12 m
No. of solar collectors	11
Total row length:	550 m
Inclination of the tracking axis:	0°,2°,4°,6°,8°
Orientation:	North-South
Absorber pipe inner/outer diameter:	50/70 mm
Mass flow per row (once-through configuration)	1 kg/s
Max. recirculation rate:	4
Max. outlet steam temperatur./pressure:	400°C/100 bar

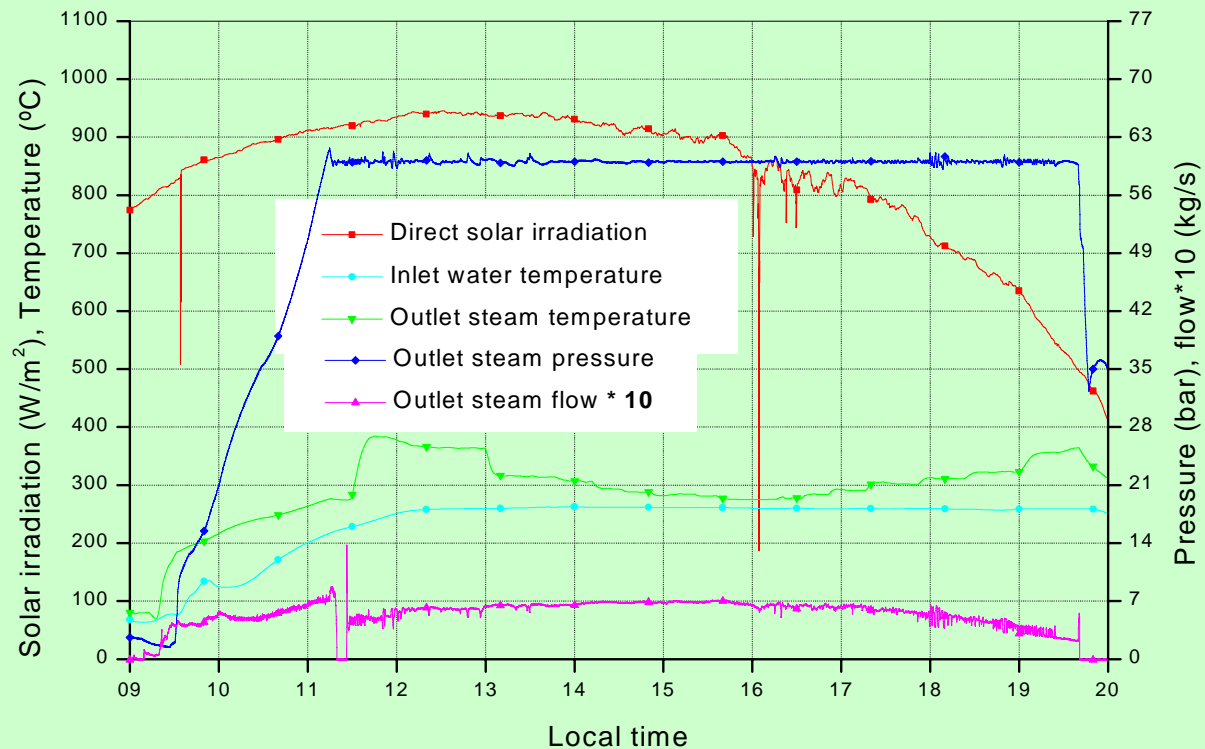


## Operation and Maintenance experience

- The DISS solar field has a great thermal inertia due to the length of the piping (>2400m) and the amount of steel parts (>26 Tons), while the length of the absorber pipes is 480m only. This problem will not affect to a DSG commercial power plant
- The open-loop sun-tracking system implemented at the DISS collectors shows a small seasonal error in summer time (<4 mrad). Investigation of this problem is still underway
- No O&M problem has been found with the 100bar/400°C ball-joints installed at the solar field
- Efficient control pressure was implemented at the solar field to avoid vacuum condition due to steam condensation overnight
- Thermal insulation and piping lay-out were improved. The start-up time was thus reduced in more than 50%
- The number of data channels (600) and the short sampling period (<1sec.) demanded the optimisation of DAS and Control system parameters to avoid undue interruptions and communication failures in the internal data transfer network

## Operation and maintenance experience

➤ The accumulated operating time of the DISS test facility in 1999 and 2000 was 2110 hours



Typical daily operation at 60 bar in Recirculation mode (June 20<sup>th</sup>, 2000)



## Main operation and maintenance problems

### Temperature measurements at the absorber pipes

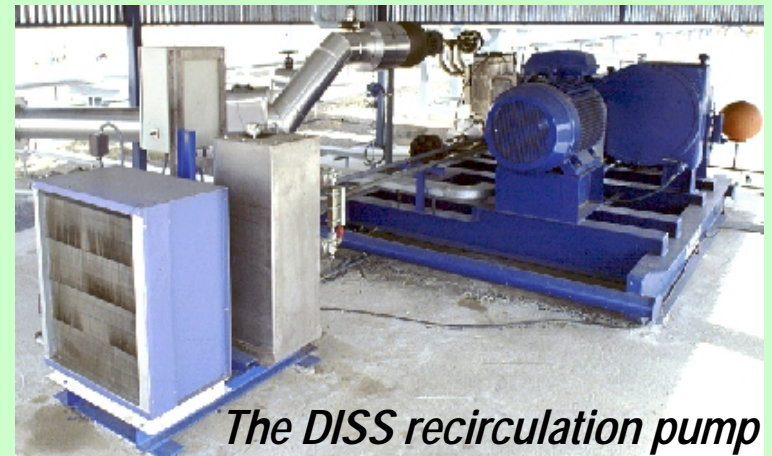
- Concentrated solar radiation onto the absorber pipes caused a measurement error. This problem was successfully solved in 2000

### D.A.S. System

- Since the Elsag&Bailey Symphony DAS System implemented at the DISS facility was the first one in Spain, it required a long time for tuning and set up. Additionally, the rate of electronic circuit cards that have to be replaced every year is extremely high ( $\cong 5\%$ )

### Water Recirculation pump failure

- The DISS water recirculation pump is a positive-displacement pump provided with three plungers. A wrong design of the packing has caused frequent failures of the pump since June, 1999. The pump manufacturer (National Oil Well, USA) has not been able to solve the problem yet



*The DISS recirculation pump*

## Main test results

- The pressure drop in the DISS solar field is 25-30% lower than predicted by simulation computer codes. Power required for pumping is therefore much smaller than in SEGS plants.

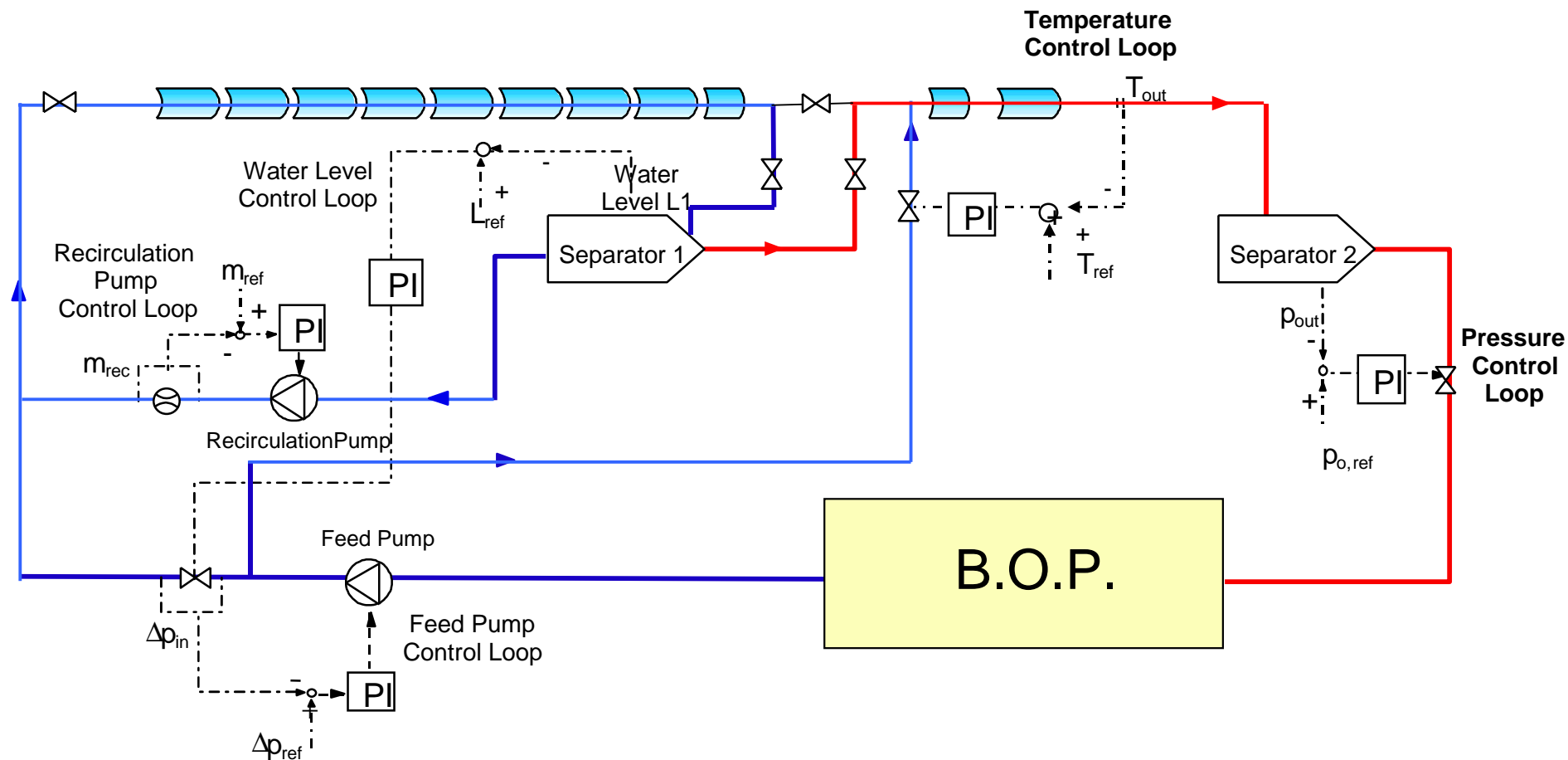
<u>Steam pressure (bar)</u>	<u>Steam flow (kg/s)</u>	<u>Overall <math>\Delta P</math> (bar, approx.)</u>
30	0.55	4.8
60	0.55	3
100	0.55	1.2

- Temperature gradients at the horizontal absorber pipes of the solar collectors are rather similar to those predicted by simulation computer codes, and they are not dangerous

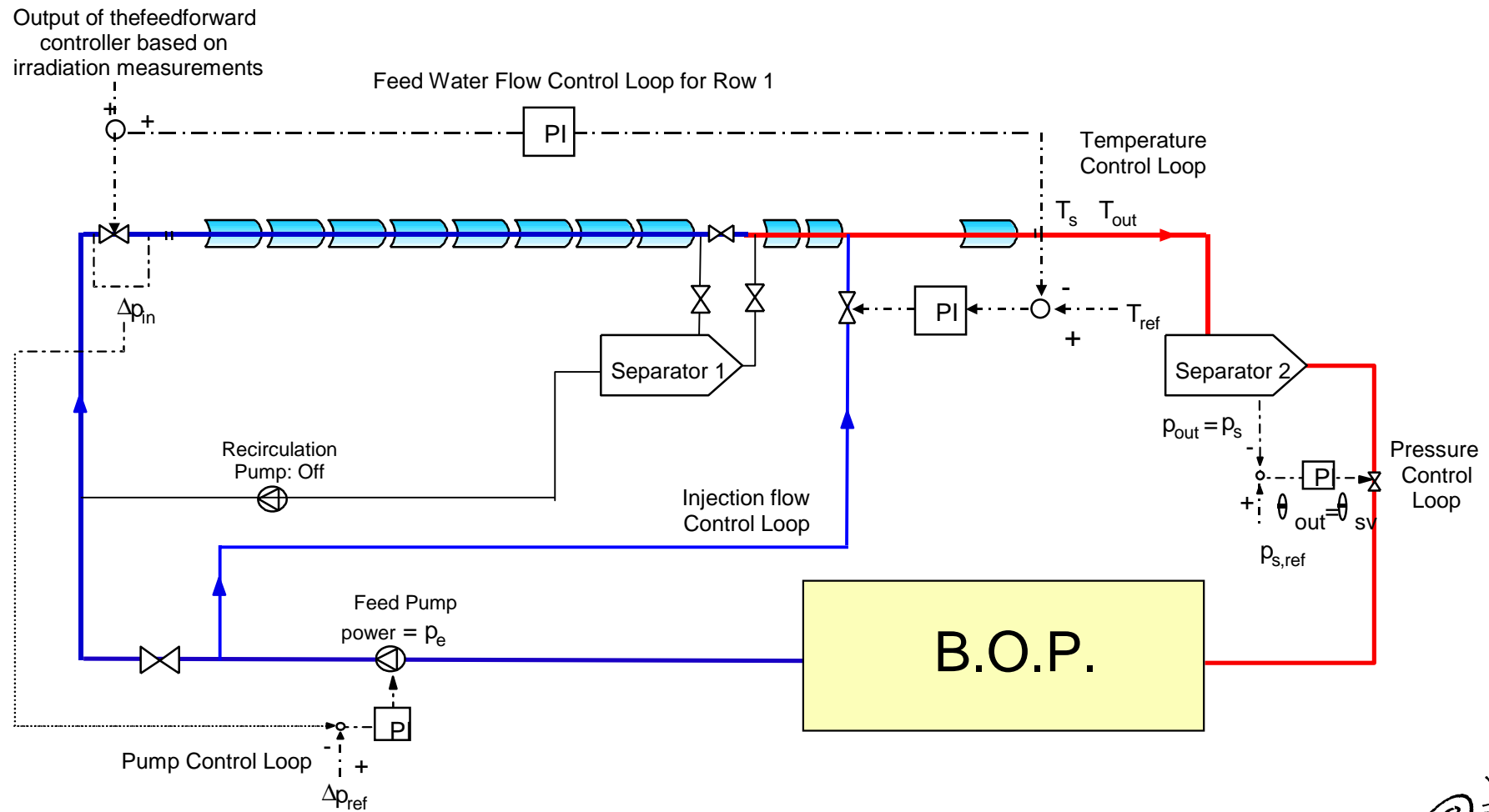
Measured  $\Delta T$  in a cross section of the absorber pipe  
(Heat flux onto the absorber: 38 kW/m<sup>2</sup>, steam flow: 0.5 kg/s)

water pre-heating: 15°C  
Water evaporation: 25-30°C  
Steam superheating: 40°C

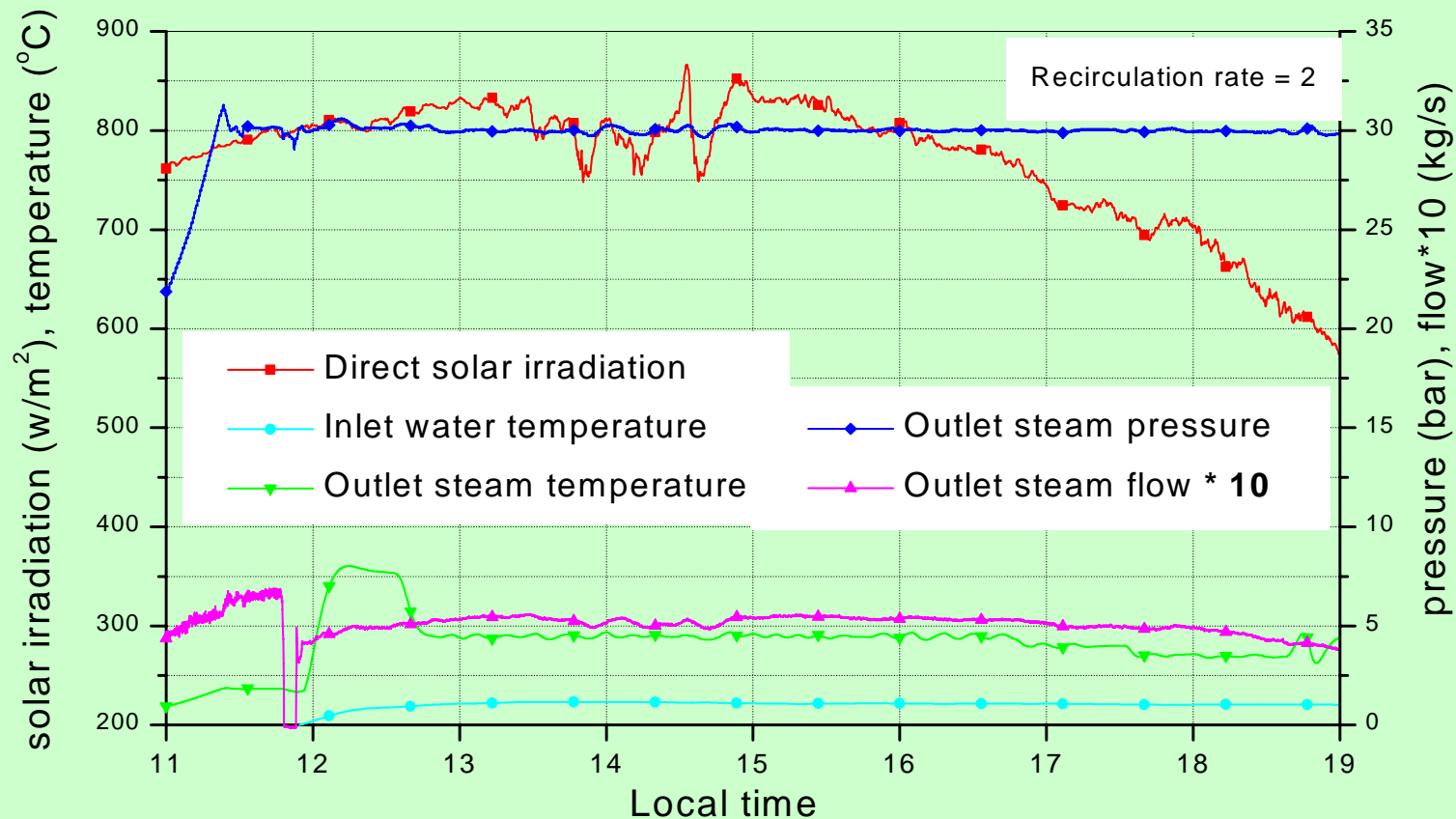
## Control Scheme for *Recirculation* process



## Control Scheme for *Once-through* process



## Control test in *Recirculation* mode



Control test performed on June 22, 2000 (Recirculation mode)

## Update of project Status

- The test facility has been operated for more than 2300 hours. 100bar, 60bar and 30 bar superheated steam was produced at 390°C in Recirculation and Once-through modes
- The PSA DISS facility has proven its usefulness to evaluate the DSG process under real solar conditions and to identify the critical issues for the design of DSG commercial plants
- It has been proven that Direct Steam Generation is feasible in horizontal absorber pipes
- Technical problems and the long initial training to operate the facility delayed the fulfilment of the planned DSG tests campaign. Nevertheless, main problems were not related to the DSG process itself, but to standard equipment (i.e., recirculation pump, electronic cards,)
- Recirculation process with low recirculation rate is a promising candidate for a commercial DSDG plant. Nevertheless, completion of the tests in Injection mode and the implementation of a multi-row DSG facility is essential to draw final conclusions
- Testing of optimised water/steam separators, design of a pre-commercial DSG power plant and production of superheated steam at 500°C will be the main objectives of next phase

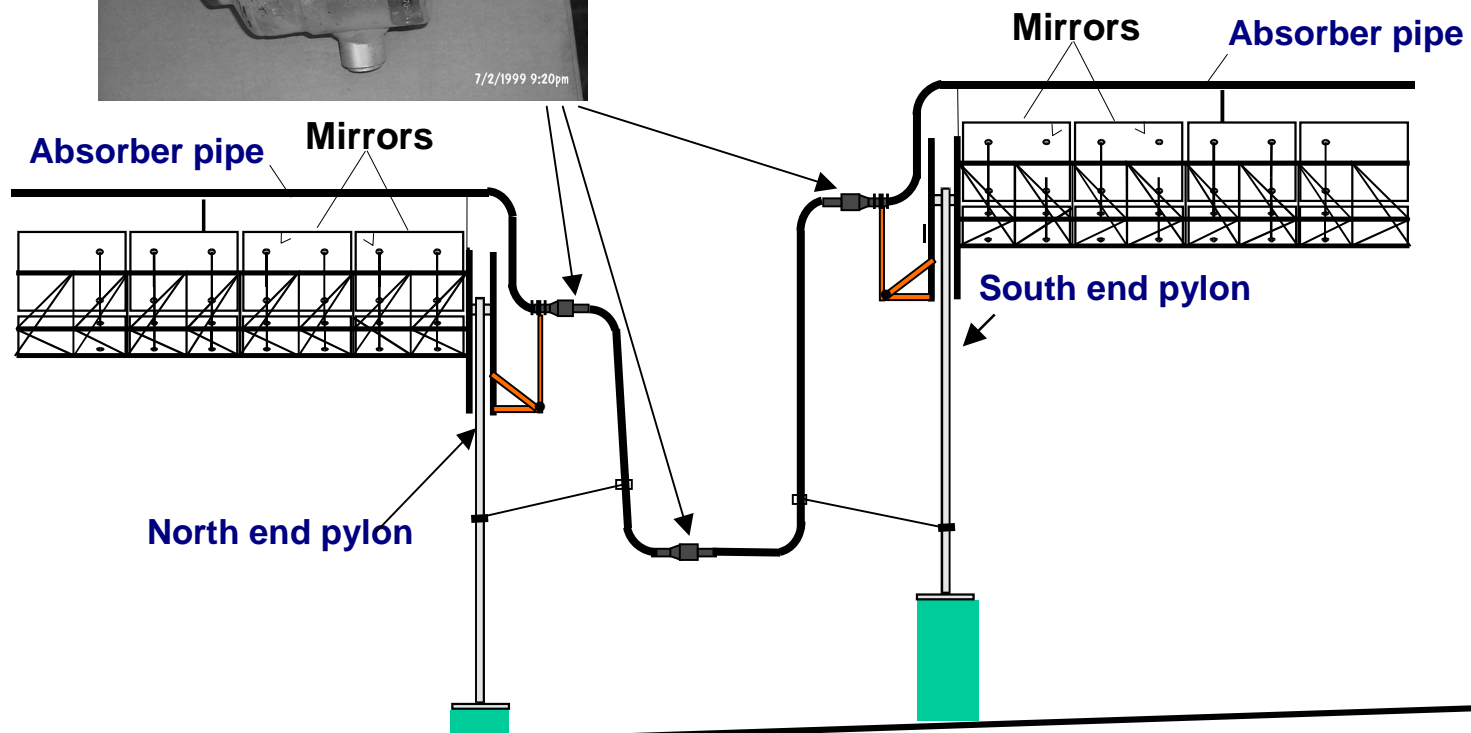
detail of a damaged plunger



damaged graphite sealings

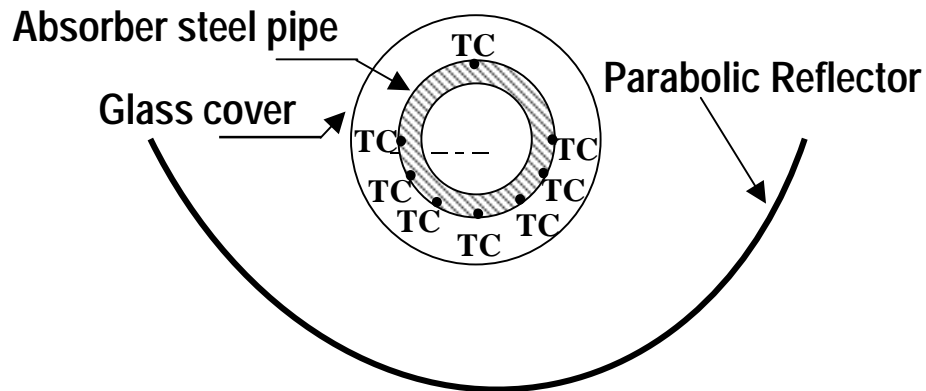
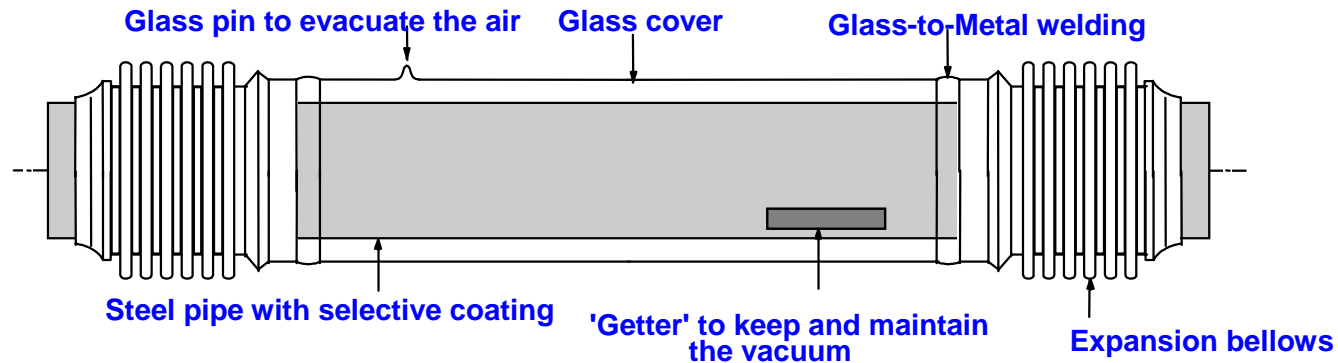


## Ball-joints installed at the DISS solar collectors

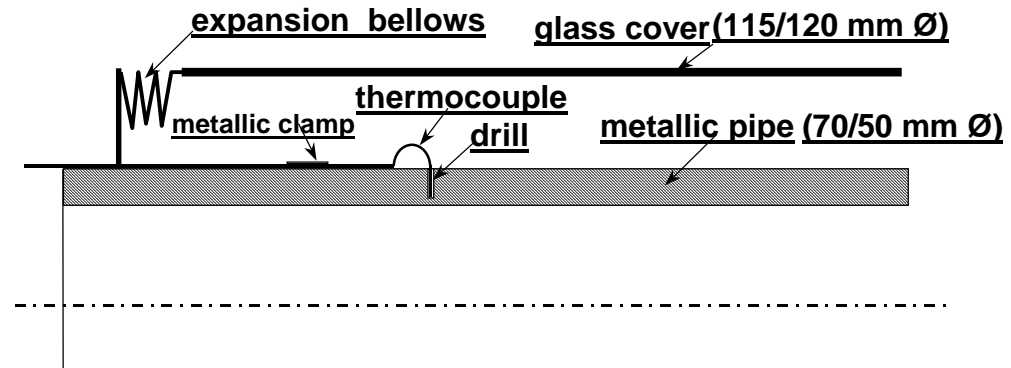




## The thermocouples installed at the absorber pipes (the so-called Test Cross Sections)



Thermocouples lay out at a Test Cross Section



Thermocouple installation at a Test Cross Section

**IMPROVEMENT OF THE THERMAL INSULATION OF TANK TK-04**



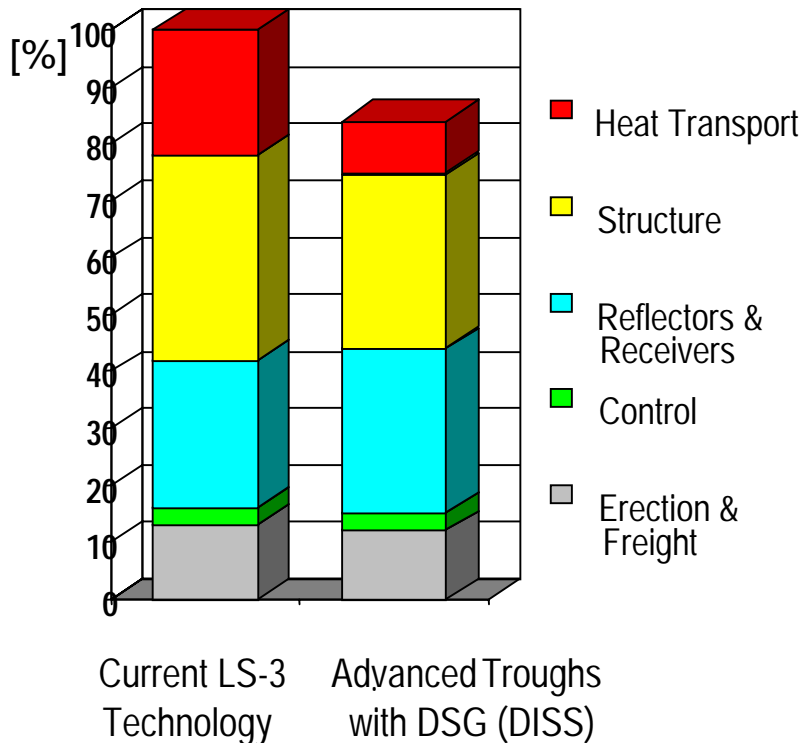
**Before the improvement**



**After the improvement**

## 25% Levelized Electricity Cost (LEC) reduction

15 % Reduction of solar field investment cost



15% Increase of annual solar field output

